III

EMISSION INVENTORY

A. METHODOLOGY FOR ESTIMATING SHIP EMISSIONS

Ship Emission Inventory Design

Marine vessels represent a significant source of emissions in the SCAB. The design objective for the emission inventory to be used for this study was to develop a detailed, day-specific emission inventory of commercial ocean-going marine vessel (ship) activities in southern California waters that could be used in the model simulations to compare the two control strategies. This level of detail is essential to accurately assess the impact of marine vessel control strategies on overall ship emissions. To accomplish this requires the collection of ship-specific activity, engine characteristics, and emission factor information. Ship-specific information is needed because each ship entering and leaving southern California waters has a unique activity profile (ship course, speed, berthing, etc.) and a unique set of emission factors based on the size of the ship, its engines, and its activity profile while operating within southern California waters. The time period selected for this study was August 3-7, 1997. This time period was selected because high ozone levels were measured in southern California during that time, and the number and types of ships operating in southern California waters during that time provide a representative cross section of ships calling at southern California ports.

Sources of Data

TWG members collected pertinent data necessary for building the emissions inventory. The U.S. Navy at Point Mugu and the Port of Los Angeles obtained information on ship activity data from the Marine Exchange of Los Angeles and Long Beach (Pera, 1998, Garrett, 1998). Average distances for the different routes in and out of the ports designated as Northern, Southern, Western, and Catalina, traveled (cruising mode) by ships in the South Coast waters and calling on the ports were obtained from "Marine Vessel Emissions Inventory and Control Strategies" (Acurex report) prepared by Acurex Environmental (Acurex, December 12, 1996). Information on maneuvering and any shifting between berths that may have occurred on the episode days was obtained from the Port of Los Angeles (POLA) and the Port of Long Beach (POLB) (Garrett 1998, Kanter, 1998). The Pacific Merchant Shipping Association provided information on stack height and emission exit temperature for commercial ships (for each ship type) (Levin, 1998). The U.S. Navy provided activity data and emissions data for the navy vessels (Osborne, 1999). John J. McMullen Associates, Inc. (JJMA) developed the ship-specific engine characteristics from Lloyd's Register of Ships (Remley, 1998). Charlotte Pera, formerly of Acurex Environmental, developed the NOx emission factors for diesel engines (auxiliary and main propulsion) using ship emission data from Lloyd's Maritime Exhaust Research Programme (Pera, 1998). Stack emission factors for diesel engines were obtained from Lloyd's Maritime Exhaust Research Programme, for steamships were obtained from U.S. EPA, and for gas turbines were obtained from General Electric through JJMA (Remley, 1998).

Ship Activity Data

The types of ships included in the inventory assessment are ocean-going vessels calling on the San Pedro Bay Ports (Ports of Los Angeles and Long Beach) and U.S. Navy vessels. Fishing vessels, tugboats and other harbor vessels, and U.S. Coast Guard vessels are not included in this inventory. This section describes ship activity in each operating mode while traveling in South Coast waters.

- Identification of Ship Modes of Operation

Emissions from ocean-going vessels occur at different rates while cruising, maneuvering, hotelling, and shifting operating modes. Each mode needs to be defined and tracked to accurately assess emissions. Ocean-going vessels enter and exit the South Coast waters in cruise mode, which is associated with a speed of about 13 to 22 knots. Ships are required to reduce speed to 12 knots within the precautionary zone, which begins about three to 5 miles from the breakwater. About one mile from the breakwater, the ships slow down to about 5 knots to take on a pilot and are then assisted by tugboats and maneuvered into the harbor. Main engines and auxiliary boilers are used during cruising (including cruising in the precautionary zone) and maneuvering modes. While hotelling, auxiliary boilers and generators (auxiliary engines) are used. The emission inventory is developed for these modes of operation. A summary of the operational modes accounted for in this analysis is presented in Table III-1.

Table III-1
Operational Modes Addressed in the Emission Inventory

Mode	Direction
Cruise	Entry (Inbound)
Cruise	Exit (Outbound)
Precautionary Zone Cruise	Entry (Inbound)
Precautionary Zone Cruise	Exit (Outbound)
Maneuvering	Entry (Inbound)
Maneuvering	Exit (Outbound)
Hotelling	-

- Commercial Shipping Arrivals and Departures

The Marine Exchange provided ship arrival and departure information for the

August 3-7,1997 SCOS episode. According to the data from the Marine Exchange, there were a total of 87 ships with 63 arrivals and 62 departures during this 5-day period. Several ships arrived and departed outside the August episode period. A summary of these data is provided in Table III-2. As shown in Table III-2, the breakdown of ships by type was 47 Container ships, 11 tankers, 9 bulk carriers, 6 vehicle carriers, 3 each of bulk/container carriers, general cargo, refrigerated cargo, and passenger, and 1 each of chemical tanker and roll-on/roll-off container carrier. A more detailed summary is provided in Table B-1 provided in Appendix B. In Table B-1, the description on the ocean-going vessel calls in August 1997 at the POLA and POLB is provided using data from the Marine Exchange based on the following parameters: ship names, ship types, propulsion type (diesel, steamship, gas turbines), arrival and departure date, time, and direction of arrival and departure, arrival and departure gate. The majority of ship calls at the San Pedro Bay Ports were of the diesel engine propulsion type. There were very few calls made by vessels using gas turbine propulsion. Roughly 50 percent of the ships entered and departed the breakwater by Angel gate (POLA) and the other 50 percent by Queen gate (POLB).

Table III-2
Ship Counts for August 3-7, 1997 Episode Based on Ship Type, Propulsion Type, Engine Type, and Arrival and Departure Gate

Ship Type	Count	Propulsion Type	Count
Bulk Carrier	9	Diesel	74
Bulk/Container Carrier	3	Gas Turbine	2
General Cargo	3	Steam	11
Refrigerated Cargo	3		
Passenger	3	Diesel Engine Type	Count
Vehicle Carrier	6	2 Stroke	68
Container Carrier	47	4 Stroke	6
Chemical Tanker	1		
Tanker	11	Gate	Count
RORO Container	1	Angel	78
TOTAL	87	Queen	96

- Maneuvering, Berthing and Hotelling

Information on maneuvering and any shifting between berths that may have occurred on the episode days was obtained from POLA and POLB. The POLA and POLB Wharfinger agency provided data on hotelling and maneuvering activities for the episode days. Default times were used from the Acurex report (Acurex, December 12, 1996), whenever ship specific information was not available. To calculate time spent hotelling, we subtracted the actual maneuvering times from the total time spent in port.

* U.S. Navy Vessel Inventory

The U.S. Navy provided day-specific ship activity data for navy vessels traveling in the SCOS97 domain north of Point conception to south of the Mexican border during the August episode (Osborne, 1999, Remley, 1998). The information on ship class, ship type, average ship speed (knots), ship positions (latitude and longitude), port visited (at pierside), time duration (hrs), start date, end date, and emission rates (kg/hr) for NOx was provided for each navy vessel (See Appendix B, Table B-2). The majority of the navy vessel activity during the August episode occurred near the port of San Diego.[4]

* Port Hueneme

Ventura County Air Pollution Control District provided ship activity data for Port Hueneme on the August episode days (McGaugh, 1999). There were eight commercial ships arriving and departing during the August episode. Ship-specific information for the vessels traveling to this port was not available to us. Therefore emissions for Port Hueneme were not included as part of this analysis. There was no U.S. Navy vessel activity at Port Hueneme during the August episode.

* Transiting Ships

Transiting ships are those vessels that travel northbound or southbound along the coast without stopping at a port. The U.S.Navy Point Mugu Range Surveillance (1997) database was used to obtain information on transiting ships (Rosenthal, 1999). The data indicated that there are very few transiting ships traveling along the Santa Barbara Channel but not coming into the ports of Los Angeles and Long Beach, approximately 3 or 4 a month. In addition, the route for transiting vessels may be very far offshore, in some cases outside the overwater boundary. Therefore, for the purposes of the comparative technical analysis of the air quality impacts between the two control options, it was agreed that the transiting ship emissions could be ignored.

Ship Machinery and Operational Characteristics

* Speed Power Curves

The power required to drive a ship varies with ship speed, cubed. In this study we used speed-power curves developed by JJMA for commercial ships (Pera, 1998, Remley, 1998). The JJMA curves were very similar to the ship speed cubed relationship.

[4] The emission inventory for Navy vessels is included in the report for informational purposes. The data was not included in the emission reduction estimates, gridded emissions or the model simulations for the comparative analysis as the data had not been completely reviewed prior to performing the analyses.

- Stack Information

The Pacific Merchant Shipping Association provided information on stack height and exit temperature for commercial ships (for each ship type). Because the stack information specific for each ship category was not available, the ships were assigned to two different categories based on the propulsion and energy generation plant configuration and average stack parameters (Levin 1998). A summary of the stack parameters is presented in Table III-3 below.

Table III-3
Stack Parameters for Container and Tanker Ship Type Categories.

	Stack Height* (meters)	Stack Diameter (millimeters)	Stack Exhaust Temp (^{0}C)	Stack Exhaust velocity (meters/second)
Container Category	37.6	2012	222	25.8
Tanker Category	32.9	1705	306	23.4

*Stack height is height of stack above the water surface.

- Engine Characteristics

Ship-specific engine characteristics were used in developing the marine vessel inventory based on the information provided by JJMA. Some of the ship-specific characteristics were 1) actual horsepower for each ship, 2) actual kilowatt (kW) information for each generator (auxiliary engine), 3) steam ship-specific fuel consumption, and 4) propulsion type-specific emission factors (diesel, steamship, turbine).

- Ship Speed

Operating speeds of ships at sea vary with the size and type of vessels and the mode of propulsion. For the base-case, ship-specific cruising speed data for this analysis were available. The TWG obtained actual speed data for 60 days (9/22/98 through 11/22/98) for ships cruising in South Coast waters. This comprised approximately 1600 records. The actual open ocean cruising speed was determined using radar readings taken by the port when the ship was 25 miles off shore. At that distance, ships are operating at their open ocean cruising speed. The actual speeds were available from radar readings for over half of the ships identified as operating in South Coast waters during the August episode.

These data indicated that on the average the actual cruising speed was less than the ship's design speed (ARCADIS, May28, 1999 and Lloyds, 1995). It also demonstrated that the difference between actual and design speed varied with each ship type. Generally, the largest variation in speed was for passenger vessels. The actual speed of the slowest and fastest vessels within each type differed by as much as 10 knots for passenger vessels and about 8 knots for container vessels. However, most of the ships within a given ship type category fell within a narrow 3-4 knot range of cruising speed.

We took advantage of this relationship by using the actual speed information to calculate a speed correction factor (SCF) by ship type. The SCF (for that particular ship type) was applied to the design speed for the ships traveling on the episode days where actual speed information was not available. Table III-4 summarizes the average actual versus the average design speed by ship type. Records that did not include a design speed or where the design speed was recorded as "0.1" (indicating missing data according to the Marine Exchange) were deleted. All the data records with speed less than 5.5 were considered erroneous and were deleted.

Table III- 4
Comparison of Actual Versus Design Speeds for Typical Ship Types

Route	Vessel Information	TYPE "C"	TYPE "P"	TYPE "T"
All	Average MAREX Speed	17.90	13.60	13.68
	Average Design Speed	19.58	20.40	15.31
	Vessel Count	1341	111	231
	Avg. count per day	22	2	4
	Speed Correction Factor	0.91	0.67	0.89
Arrivals	Average MAREX Speed	17.56	13.21	13.51
	Average Design Speed	19.60	20.39	15.30
	Vessel Count	665	55	112
	Maxspeed Diff.	Hanjin Malta (14.89)	Holiday (14.01)	Columbia (11.48)
Departures	Average MAREX Speed	18.23	13.97	13.84
	Average Design Speed	19.56	20.41	15.32
	Vessel Count	676	56	119
	Maxspeed Diff.	Luhe (11.93)	Mercury (14.94)	Columbia (11.96)

Notes: "Design Speed" is Lloyd's design speed. "C" represents Cargo carriers such as containers, auto carriers, and breakbulk. "P" represents passenger vessels and "T," liquid bulk carriers. "Maxspeed Diff." is the difference of the design speed and MAREX speed.

In the precautionary zone, ships are required to travel at 12 knots. As a general practice, they begin slowing down about three to 5 miles before the breakwater so that they are at the mandatory 5-knot speed when entering the breakwater (ACUREX, 1996). The TWG agreed to not account for the slowing down between 12 and 5 knots, as this would probably be in the "noise" of the model and for the comparative analysis, would not affect the comparison between the two control strategies. Therefore, it was assumed that ships are cruising at 12 knots in the precautionary zone and 5 knots in the breakwater.

- Engine Loads

Engine Loads differ with every mode of operation. Cruise mode is associated with an engine load of approximately 80 percent maximum continuous rating (MCR). For precautionary zone cruising the following assumptions were made. In the precautionary zone, ships are required to travel at or below 12 knots. The percent MCR at 12 knots was estimated using the ratio of 12 knots to the actual or design speed of each ship. The implied percent power was calculated using 80 percent of the speed ratio cubed. During maneuvering mode, information from the Acurex report (Acurex, December 12, 1996) was used to obtain the percent MCR at an average speed of 5 knots. Maneuvering at 20 percent MCR was assumed for bulk carriers, general cargo, and tankers. Container ships were assumed to maneuver at 10 percent MCR, and remaining ships were assumed to maneuver at 15 percent MCR. Information on engine loads within the breakwater was very difficult to obtain and so it was recommended by the TWG to not pursue it further.

- Emission Factors

Emission factors in grams per kilowatt-hour (g/kWh) of energy output were used to estimate NOx emissions from main engines and generators (auxiliary engines). The TWG agreed to use emission factors based on energy output (for example grams of NOx/kWh) for the following reasons: 1) there is some uncertainty in the brake-specific fuel consumption (BSFC) factor needed to calculate the emission factor based on fuel consumption, 2) very limited information is available on projected fuel usage in future years, and 3) the energy output based emission factors are independent of fuel consumption rates and therefore eliminate the need to account for future changes in ship fuel efficiencies (ARCADIS, May 6, 1999, and ARCADIS May 28, 1999).

The cruising and maneuvering main engines (diesel) NOx emission factors at different engine loads were developed by ARCADIS for NOx as shown in Table III-5. Average NOx emission factors for slow and medium speed engines were estimated to be 17 and 12 g/kWh (87 and 57 kg/tonne fuel), respectively. The only distinction made for NOx was between slow and medium speed emission factors (ARCADIS, May 6, 1999 and Lloyds, 1995).

Table III-5
NOx Emission Factors in grams/kWh

%MCR	80%	40%	35%	20%	15%	10%
Slow Speed NOx	17.32	18.04	18.13	18.41	18.5	18.59
Medium Speed NOx	12.81	14.03	14.18	14.64	14.79	14.94

For generators, medium speed emission factors were assumed for all modes. For auxiliary boilers, emission factors in pounds per hour were used (ARCADIS, May 6, 1999, ACUREX 1996, ARCADIS, May 28, 1999). The NOx emission factors for steamships were obtained from the U.S. EPA AP-42 document. (U.S. EPA, 1985) The gas turbines emission factors were developed by GE and provided by JJMA (Remley, 1998).

Emission Calculations

Base Case Inventory

- Commercial Vessels

This section summarizes the preliminary estimates of NOx emissions for the August 3-7,1997 SCOS episode (See Table III-6). To calculate emissions, we used the total amount of time spent cruising, maneuvering, and hotelling in the SCAB waters. To estimate main engine emissions, the main engine horsepower for each ship was multiplied by the energy output factor (g/kWh) and by the total number of hours estimated for that mode (i.e., cruising, precautionary zone cruising, etc). For example, for cruise mode, 80 percent of the actual horsepower for each ship was multiplied by the time spent in the entry and exit cruise modes, and the emission factors. Several variables are needed to estimate the emissions associated with each of these modes. As an example, to estimate the emissions associated with the in-bound or entry cruising, the following data are necessary: entry cruise distance, actual speed, engine horsepower (Lloyds), cruise speed at 80 percent MCR power, entry cruise hp-hr, entry cruise kWh, and EMSFAC cruise g/kWh. This is represented by the following equation:

*(Entry Cruise Distance/speed) * (80% MCR of actual HP value) * (Emission factor g/kWh) = NOx emissions*

For generators, the following approach was used to estimate NOx emissions. The generators were assumed to be medium speed engines. The generator rated kW (largest size generator for each ship) was multiplied by the load factor (80 percent for cruising, precautionary zone cruising, and maneuvering and 55 percent for hotelling) and the time spent in each mode and medium speed engine emission factors.

For auxiliary boilers, we used the methodology adopted in the ARCADIS report (ARCADIS May 28, 1999). We estimated auxiliary boiler emissions in cruising, maneuvering, and hotelling modes.

For steamships, the emission calculations are slightly different since the steamship emissions are based on the ship's boiler fuel consumption. The propulsion and auxiliary engines (generators) in the case of steamships are steam turbines that do not have any emissions. The emissions are from the main boilers, which generate the steam that powers the turbines. For steam ships, emission factors for residual fuel (55.8 lbs. NOx/1000 gallon fuel for cruise mode and 36.8 lbs. NOx/1000 gallon fuel for hotelling) were used. The emission factors vary with mode because of the load on the main boilers. While cruising, the boilers are highly loaded and so produce more NOx per gallon of fuel burned than when they are in port and are not as highly loaded.

Based on the energy output methodology, approximately 115 tons (23 tons per day) of NOx was estimated from ship activity for the 5-day August episode. This comprehensive estimate takes into account the main engine/boiler-cruising and maneuvering emissions; generator (auxiliary engine)-cruising, maneuvering, and hotelling emissions; and auxiliary boiler-maneuvering and hotelling emissions. As a comparison, the Acurex Report (December 12, 1996) estimated emissions of 21.6 tons per day (TPD) and the 1995 Annual Average emissions inventory for the SCAB is 29 TPD.

Table III-6
Baseline NOx Emissions (tons) for the Existing MAREX In-Bound and Out-Bound Shipping Lanes for 5-Day August Episode

Main Engines						Auxiliary Boilers		
Entry Cruise	Exit Cruise	Entry PZC	Exit PZC	Entry Maneuvering	Exit Maneuvering	Entry All Cruise	Exit All Cruise	Hotelling + Maneuvering
31.5	38	3.1	2.6	2.3	2.0	0.2	0.2	7.5

Generators							Total NOx
Entry Cruise	Exit Cruise	Entry PZC	Exit PZC	Entry Maneuvering	Exit Maneuvering	Hotelling	
1.7	1.9	0.4	0.4	0.7	0.6	22.1	115.4 (2.3 tpd)

- Naval Ship Emissions

This section provides the preliminary U.S. Navy vessel NOx emission estimates for the August 3-7, 1997 SCOS episode. These emissions pertain to cruising mode only. Average ship speed is calculated from ship's log data for the respective time intervals. While in port, navy vessels are in a cold iron status and engines are completely shut down, therefore, there are no exhaust emissions. The NOx emissions from U.S. Navy vessels for the entire SCOS domain were 15 tons for the entire August episode.

Emission Estimates for the Base Case and Speed Reduction Modeling Scenarios

Emission estimates were prepared for the three voluntary speed reduction scenarios and the base case. Estimates were not prepared for the proposed relocation of the shipping lane due to the complexity of the calculations and resource availability. For the proposed shipping lane, only the gridded emissions estimate was prepared. (See the next section B, "Gridded Emissions Model.")

The three potential speed reduction scenarios have been discussed previously. To briefly recap they are:

1) Scenario #1: extending the precautionary zone 12-knot speed limit to 20 miles;
2) Scenario #2: extending the precautionary zone 12-knot speed limit to the SCAB overwater boundary; and
3) Scenario #3: a speed limit of 15-knots between the precautionary zone and the SCAB overwater boundary.

In Table III-7 the estimated emissions for the August 3-7, 1997 episode for the base case (uncontrolled) and each of the speed reduction scenarios are presented. Only the emissions in the SCAB are included in the estimates. Total emissions are presented as well as the emissions for the main engines, generators, and auxiliary boilers.

Table III-7
NOx Emissions for Base Case and Speed Reduction Scenarios

Scenario	Main Engines	Generators (Tons)	Auxiliary Boiler	Total (Tons)
Base Case	79.5	27.9	8.0	115.4
Scenario #1	66.8	28.5	8.0	103.3
Scenario #2	44.8	29.5	8.1	82.5
Scenario #3	57.0	28.7	8.0	93.7

The estimated average transit time for specific ship types under the speed reduction control scenarios #1, #2, and #3 are summarized in Table III-8 below.

Table III-8
Average Transit Times (minutes) for Specific Ship Types Under Speed Reduction Control Scenarios for August 4, 1997

	Basecase					Scenario 1				
Type	Cruise Entry	Cruise Exit	PZC Entry	PZC Exit	Total	Cruise Entry	Cruise Exit	PZC Entry	PZC Exit	Total
BBU(5)	180	176	35	25	416	120	109	94	102	425
GGC (2)	156	159	39	30	384	102	102	102	102	408
GRF (2)	123	126	30	24	303	78	78	102	102	360
MPR (2)	183	204	40	32	458	117	129	111	111	468
MVE (2)	150	144	33	24	351	99	90	102	101	392
TTA (3)	154	162	38	30	384	98	108	102	102	410
UCC (20)	120	126	34	25	304	78	80	102	102	362

Table III-8 (cont.)

	Scenario 2					Scenario 3				
Type	Cruise Entry	Cruise Exit	PZC Entry	PZC Exit	Total	Cruise Entry	Cruise Exit	PZC Entry	PZC Exit	Total
BBU(5)	0	0	199	222	421	180	176	35	25	416
GGC (2)	0	0	222	222	444	156	162	39	30	387
GRF (2)	0	0	216	216	432	150	156	30	24	360
MPR (2)	0	0	222	234	456	183	204	42	30	459
MVE (2)	0	0	234	221	455	162	156	33	24	375
TTA (3)	0	0	222	232	454	156	166	38	30	390
UCC (20)	0	0	224	228	452	155	161	34	25	374

Notes: ()=Number in Parenthesis represents the count for the August 4, 1997. Totals may not match due to rounding. The following abbreviations are used to identify the ship types: Bulk Carrier (BBU); Bulk/Container Carrier (BCB); General Cargo (GGC); Refrigerated Cargo (GRF); Passenger (MPR); Vehicle Carrier (MVE); Chemical Tanker (TCH); Tanker (TTA); Container Carrier (UCC); and RORO Container Carrier (URC).

To determine transit times for the proposed shipping lanes, the following methodology was used. First, only those ships arriving from the north (52 ships) or departing to the north (47 ships) were used in the calculation since the proposed change in the shipping lane only affects this route. The next step was to disregard those ships transiting within the SCOS97 domain at the start or end of the August 3-7 episode, since transit times from the edge of the domain to port or vice versa could not be determined for those ships. For the remaining ships (33 arriving from the north and 30 departing to the north), the difference in transit times between the current and proposed shipping lanes was determined; these values were then averaged. The results are summarized in Table III-9.

Table III-9
Difference in Average Transit Times (minutes) for the Base Case and Speed Reduction Scenarios for the Proposed Shipping Lanes

	Scenario #1	Scenario #2	Scenario #3	Proposed Shipping Lane
Arrivals	30	62	27	63
Departures	33	67	32	57

B. GRIDDED EMISSIONS MODEL

The ship activity and emission factor data for August 3-7, 1997, were provided as input to a computer model to calculate gridded ship NO_x emissions for the modeling region (described below). Gridded emission totals for the region and for the South Coast waters only were calculated for the base case (current shipping lanes), the proposed shipping lanes, and for each of three voluntary speed reduction scenarios. Below we briefly describe the model and domain used, and then provide the gridded emission totals.

<u>Model Domain and Description</u>

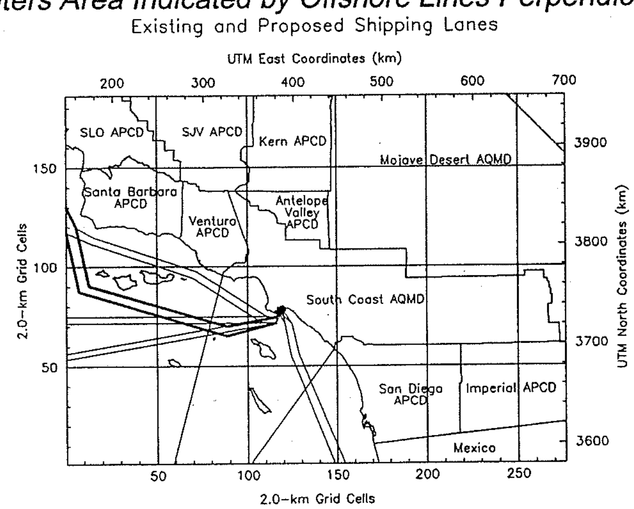
The model first establishes the domain to be gridded, based on user-specified information on the desired origin, grid resolution, and number of cells in each direction. For the ship gridding, the domain was defined by the following:

Origin:	150 km UTM East 3580 km UTM North
Grid cell resolution:	2 km
Number of grid cells in east-west direction:	275
Number of grid cells in north-south direction:	185

Figure III-1 shows the domain used. An additional requirement for this study was the need to determine shipping emissions within the South Coast waters only; this region is indicated in the figure by the offshore lines perpendicular to the coastline at the boundaries of the South Coast.

After the domain has been established, the coordinates for the various paths (North, South, West, and Catalina routes) are then read in, and for each cell that the path intersects the cell coordinates and distance in that cell are determined. For the proposed shipping lanes scenario, the model is simply re-run with the coordinates for the existing lane replaced by those from the proposed lanes.

Figure III-1
Gridded Shipping Inventory Domain
Proposed Shipping Lanes in Bold
South Coast Waters Area Indicated by Offshore Lines Perpendicular to Coastline



The following information (described in Section III.A) is needed for each ship to create the gridded ship emission inventory:

- ship name
- speed
- cruising power
- maneuvering power
- vessel type
- engine type
- number of cylinders
- arrival information (gate, direction, date, time)
- departure information (gate, direction, date, time)
- entry and exit maneuvering times
- stack parameters
- emission factors at different power levels

For ships, which entered port, the entry path is determined and the ship is taken backward in time from the entry port along the entry path, using the port entry time. This step includes time spent maneuvering in port. The emissions in each grid cell are determined from the ship speed, distance of the route within the cell, and the appropriate emission factor. Similarly, ships which left port are taken forward in time along the exit path. The emissions for the hotelling time in port are added to the port cell data.

<u>Gridded Emission Inventories</u>

The gridded emissions model was used to calculate ship NO_x emissions for the modeling region and for the South Coast waters only, for the base case (existing shipping lanes), the proposed shipping lanes, and for each of three voluntary speed reduction scenarios. The speed reduction scenarios have been described previously, however they can be summarized as follows:

Speed Reduction Scenario #1: Based on the current shipping lanes with the precautionary zone speed limit of 12 knots extended to 20 miles.

Speed Reduction Scenario #2: Based on the current shipping lanes with the precautionary zone speed limit of 12 knots extended to the overwater boundary of the SCAB waters.

Speed Reduction Scenario #3: Based on the current shipping lanes with the existing 12-knot precautionary zone. A speed limit of 15 knots is applied between the overwater boundary of the SCAB waters and the precautionary zone.

Tables III-10 and III-11 below summarize ship NO_x emission totals for August 3-7, 1997, for the modeling region and SCAB waters only, respectively.

Table III-10
Gridded Ship NO_x Emissions Totals (tons) for August 3-7, 1997
(Entire Modeling Region)

Scenario	*Aug. 3*	*Aug. 4*	*Aug. 5*	*Aug. 6*	*Aug. 7*	*Aug. 3-7*	*Avg. change per day from base case*
Current Shipping Lane *(Base Case)*	60.47	67.35	34.81	45.21	57.98	265.82	
Proposed Shipping Lane	65.09	72.31	37.30	49.00	62.38	286.08	4.05
Speed Reduction Scenario #1	57.67	63.18	32.37	44.10	52.63	249.95	-3.17
Speed Reduction Scenario #2	53.39	58.68	31.06	41.56	45.98	230.67	-7.03
Speed Reduction Scenario #3	56.55	61.86	32.05	43.41	50.97	244.84	-4.20

Table III-11
Gridded Ship NO_x Emissions Totals (tons) for August 3-7, 1997
(South Coast Air Basin Waters Only)

Scenario	*Aug. 3*	*Aug. 4*	*Aug. 5*	*Aug. 6*	*Aug. 7*	*Aug. 3-7*	*Avg. change per day from base case*
Current Shipping Lane *(Base Case)*	26.14	30.17	15.12	18.71	24.64	114.78	
Proposed Shipping Lane	26.73	30.80	15.42	18.99	25.37	117.31	0.51
Speed Reduction Scenario #1	23.59	26.38	12.57	16.92	20.50	99.96	-2.96
Speed Reduction Scenario #2	19.62	22.32	10.78	13.75	15.64	82.11	-6.53
Speed Reduction Scenario #3	22.31	25.13	12.35	16.15	18.94	94.88	-3.98

As shown by Table III-11, NO_x emissions within the SCAB waters vary significantly by day, due to differences in activity. However, the NO_x tonnage reductions within the SCAB waters are greatest for voluntary speed reduction scenario #2, and are slightly higher for the proposed lanes than for the existing lanes. These directional changes are consistent across all days, although their magnitude is not.

During the stakeholder meetings, a question arose as to why there are larger differences in daily emissions in the SCOS97 domain than in the South Coast waters for the different speed reduction scenarios, since those scenarios only change the maximum speed in different parts of the South Coast waters. It turns out that this difference is simply an artifact of reporting emissions on a daily basis. Any speed reduction in the South Coast waters reduces the amount of time that a ship spends in the rest of the SCOS97 domain for any given day.

As an example, consider one ship in particular, the Tundra King. The Tundra King arrived at the port of Los Angeles on August 4, 1997 at 0640 from the north, and departed to the south that same day at 1935. The average cruise speed was 18.2 knots. Table III-12 summarizes when the Tundra King reached different locations. The only information we have on the location of the Tundra King are the times of arrival and departure from port. The other times are determined by the assumed speed, which varies with scenario.

Table III-12
Estimated Arrival and Departure Times for the Tundra King

	Base Case	Speed Reduction Scenario #1	Speed Reduction Scenario #2	Speed Reduction Scenario #3
Arrives in port	0640 on 8/4	0640 on 8/4	0640 on 8/4	0640 on 8/4
Arrives South Coast waters	0401 on 8/4	0330 on 8/4	0255 on 8/4	0334 on 8/4
Arrives in SCOS domain	2246 on 8/3	2214 on 8/3	2140 on 8/3	2219 on 8/3
Leaves port	1935 on 8/4	1935 on 8/4	1935 on 8/4	1935 on 8/4
Leaves South Coast waters	2216 on 8/4	2239 on 8/4	2322 on 8/4	2243 on 8/4
Leaves SCOS domain	0046 on 8/5	0109 on 8/5	0152 on 8/5	0113 on 8/5

From the above table, we can see that the Tundra King spends the same amount of time in the SCOS97 domain outside of the SCAB waters for all scenarios: 5 hours, 15 minutes on the way in, and 2 hours, 30 minutes on the way out. However, the amount of time spent in the SCOS97 domain outside of the SCAB waters *on August 4* varies among the scenarios. This explains the larger differences in daily emissions in the SCOS97 domain than in the SCAB waters for the different speed reduction scenarios.

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IV

TRACER DISPERSION STUDY

As discussed previously, the stakeholders funded a tracer dispersion study to provide sound scientific data on the transport of vessel emissions from ships traversing the shipping channel. The tracer study was conducted during the SCOS97 to take advantage of the enhanced data collection efforts associated with SCOS97. The overall objectives of the tracer study were to:

1. provide regulatory agencies and stakeholder organizations with scientifically valid information for decision making regarding the impact of atmospheric emissions from the current and proposed shipping lanes on ozone episodes in the South Coast Air Basin;
2. provide data to validate meteorological models; and
3. the extent possible, conduct a study which will utilize and augment SCOS97.

The primary objective of the study was to obtain direct scientific evidence regarding the trajectory of emissions from vessels transiting the coast and the relative impact of shipping emissions on onshore air quality, specifically from the current and proposed shipping lanes. While ship emissions include several pollutants (SO_x, PM, CO, and NO_x), NO_x emissions from ships were subsequently identified by the technical working group as the pollutant of focus, since the 1994 and 1997 SIP measure M13 requires reductions in NO_x emissions from marine vessels. A secondary objective was to assess the ability of meteorological models to simulate the relevant physical processes that take place during transport of emissions from the shipping lanes to onshore locations in southern California. Successful validation of meteorological models would allow use of those models to numerically assess the relative difference in impacts from shipping emissions for a relocated shipping lane and from voluntary speed reduction scenarios.

The following sections provide a discussion of the tracer study and how the resulting data were analyzed, including quality assurance of the data and how the data were normalized to account for differences between compounds and releases.

A. TRACER STUDY TESTS

The tracer study design entailed releasing known quantities of tracer gases at prescribed times and locations with the release location reflecting the distance offshore of the existing vessel traffic lanes as well as the proposed relocated traffic lanes further offshore. Monitoring equipment on land and offshore then recorded the concentrations of tracer gases reaching the shore. The feasibility of this type of overwater/coastal area tracer study was established by a review of inert gaseous atmospheric tracer studies for the period of 1970-1990 (Tracer ES&T 1997a). The tracer releases and sampling as well as the targeted meteorology, sampler locations, tracer selection, and field operational logistics are described in a series of deliverables to the stakeholders (Tracer ES&T 1997a, 1997b, 1997c, 1998). In this section we briefly summarize key aspects of the tracer study, however the reader is referred to the deliverables for more detail on the study design and scope.

The tracer experiments were targeted for high ozone episodes in the South Coast Air Basin. Ideal episodes were identified as those with weak on-shore flow combined with very warm and clear skies. Both passive and sequential time-averaging samplers were employed during the study. Thirty (30) locations had automated sequential samplers (called BATS) which collected concurrent 2-hour or 1-hour sequential air samples throughout a 46-hour test window. Passive samplers (called CATS) were employed at 21 locations; these samplers collected approximately 24 hour averaged samples. Four sites had co-located CATS and BATS samplers. Figure IV-1 shows the sampling network; Table IV-1 lists the site locations.

Figure IV-1
Sampling Network

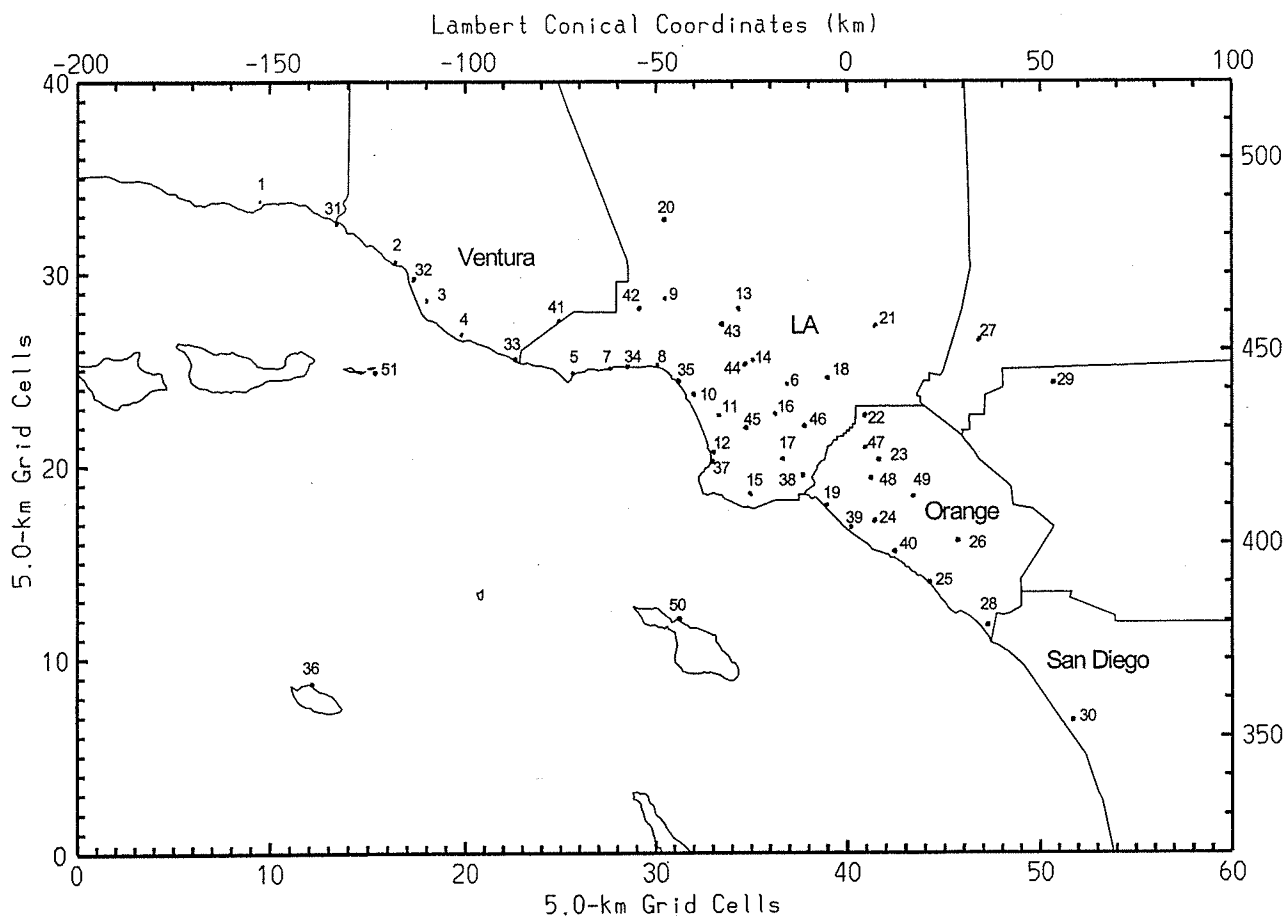


Table IV-1
Sampler Locations

Site No.	Site Location	Sampler Type(s) and Averaging Times		
		BATS		CATS
		1-hour	2-hour	24-hour
1	Santa Barbara		✓	
2	Ventura		✓	
3	Oxnard Airport		✓	
4	Pt. Mugu Naval Air Station		✓	
5	Pt. Dume Fire Station		✓	
6	Vernon Fire Station	✓		
7	Malibu Beach Fire Station		✓	
8	Castellemare Fire Station	✓		
9	Reseda SCAQMD Station		✓	
10	Marina Del Rey (LA Sheriff's Dept.)	✓		✓
11	Hawthorne SCAQMD Station	✓		✓
12	Redondo Beach Fire Station	✓		✓
13	Burbank SCAQMD Station		✓	
14	Westlake Fire Station	✓		
15	Port of Los Angeles	✓		✓
16	Lynwood SCAQMD Station		✓	
17	Long Beach SCAQMD Station		✓	
18	Pico Rivera SCAQMD Station	✓		
19	Huntington Beach Fire Station		✓	
20	Santa Clarita SCAQMD Station		✓	
21	Azusa SCAQMD Station		✓	
22	La Habra SCAQMD Station		✓	
23	Anaheim SCAQMD Station		✓	
24	Costa Mesa SCAQMD Station		✓	
25	Laguna Beach Fire Station		✓	
26	El Toro Fire Station		✓	
27	Upland SCAQMD Station		✓	
28	San Clemente Fire Station		✓	
29	Rubidoux SCAQMD Station		✓	
30	Oceanside SDAPCD Station		✓	
31	Rincon			✓
32	Harbor Blvd. (Ventura)			✓
33	Leo Carrillo			✓
34	Las Flores Canyon Rd. (Malibu)			✓
35	Crescent Park (Santa Monica)			✓
36	San Nicolas Island			✓
37	Miramar Park (Torrance)			✓
38	Los Altos Plaza Park (Long Beach)			✓
39	Manning Park (Huntington Beach)			✓
40	Grant Howard Park (Newport Beach)			✓
41	Westlake			✓
42	Warner Ranch Park			✓
43	Weddington Park (Universal City)			✓
44	Loyola High School (Los Angeles)			✓
45	Memorial Hospital of Gardena			✓
46	Bellflower Fire Station			✓
47	John Marshall Park (Anaheim)			✓
48	Community Center Park (Garden Grove)			✓
49	Frontier Park (Tustin)			✓
50	Santa Catalina Island			✓
51	Anacapa Island			✓

Five perfluorocarbon tracers (PFTs) were chosen for use in the study. PFTs were chosen as tracers because of their low global background levels and their superior detectability. These factors allow tracer tests to be conducted using minimal amounts of the PFTs, which result in substantial cost savings over other tracers. In addition, PFTs are physically and chemically inert. This prevents losses in the atmosphere and means that they are environmentally safe. The specific chemical names, abbreviations, and molecular weights for those PFTs used in this study are provided in Table IV-2 below.

Table IV-2
Perfluorocarbon Tracers

Tracer Chemical Name	Abbreviation	Molecular Weight (g/mole)
Perfluoromethylcyclopentane	PMCP	300
Perfluoromethylcyclohexane	PMCH	350
Perfluoro-1,2-dimethylcyclohexane	PDCH	400
Perfluorotrimethylcyclohexane	PTCH	450
Perfluorodimethylcyclobutane	PDCB	300

Quality assurance activities performed by the contractor included internal performance audits and field visits, contamination and leak checks, blank and co-located sample analysis, and tracer purity checks.

Two background studies were conducted to prepare for the field study. Each background study utilized CATS samplers only. The samplers were placed to detect if there were any upwind sources of the tracers planned for use in the field study. The tracer concentrations obtained during the background studies were also used by the contractor to report field study concentrations above background levels.

Following the background tests, a series of three tracer tests were conducted to measure the atmospheric impacts from releases in the existing and proposed shipping lanes. A fourth test was cancelled in progress when the oil spill response vessels used to release the tracer gases were recalled to port due to an oil spill in Santa Barbara. Table IV-3 summarizes the tests. For the tests, two release configurations were employed. One was a moving point source configuration wherein tracer gases were released continuously from vessels moving simultaneously along the existing and proposed shipping lanes. The other release configuration was a "fixed point" configuration. In this configuration the tracer gases were released from a stationary or fixed point within each shipping lane and the tracer gases were continuously released for a specified period of time.

Table IV-3
Summary of Tracer Tests

Test #	Tracer Release Date
1	August 23, 1997
2	September 4, 1997
3	September 29, 1997 *(cancelled)*
4	October 4, 1997

For test #1, the five tracer gases were released from three different vessels (see Figure IV-2). Two tracers were released from a moving source in the current shipping lane. Two separate tracers were released from a moving source in the proposed shipping lane. The remaining tracer was released as a stationary point source at the separation point common to both shipping lanes. Table IV-4 summarizes tracer test #1.

Figure IV-2
Tracers and Release Locations for Test #1

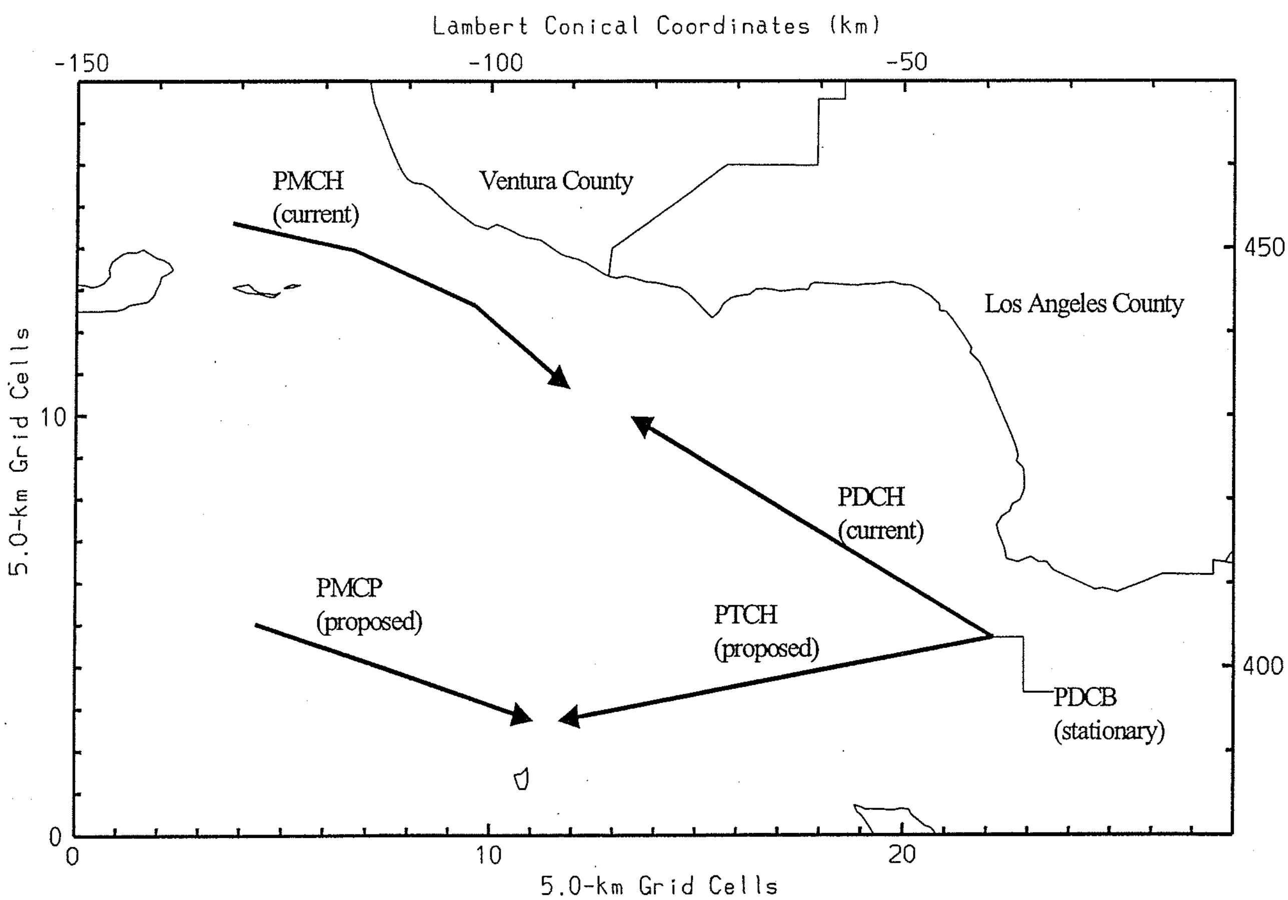


Table IV-4
Summary of Tracer Test #1
(August 23-24, 1997)

Shipping Lane	Tracer	Release Type	Release Start Time	Release End Time	Tracer Released (g)	Average Release Rate (kg/hr)	Average Vessel Speed (mph)
Current	PDCH	Moving	0400	0700	2,910	0.97	10.7
Proposed	PTCH	Moving	0401	0655	3,085	1.06	11.6
Both	PDCB	Stationary	0408	0608	3,215	1.61	0.0
Current	PMCH	Moving	1200	1500	2,835	0.95	9.6
Proposed	PMCP	Moving	1058	1400	2,720	0.90	7.3

Five tracers were also released for test #2, from two different vessels (see Figure IV-3). Except for minor differences in release times, the tracer release details were the same as for test #1. Two tracers were released from a moving source in the current shipping lane. Two separate tracers were released from a moving source in the proposed shipping lane. The remaining tracer was released as a stationary point source at the separation point common to both shipping lanes. Table IV-5 summarizes tracer test #2.

Table IV-5
Summary of Tracer Test #2
(September 4-5, 1997)

Shipping Lane	Tracer	Release Type	Release Start Time	Release End Time	Tracer Released (g)	Average Release Rate (kg/hr)	Average Vessel Speed (mph)
Current	PDCH	Moving	0755	1055	3,470	1.16	12.4
Proposed	PTCH	Moving	0750	1055	2,800	0.91	10.3
Both	PDCB	Stationary	0220	0400	940	0.56	0.0
Current	PMCH	Moving	1200	1440	2,350	0.88	11.9
Proposed	PMCP	Moving	1200	1430	2,990	1.20	10.6

The plan for test #3 was to release the five tracer gases from two vessels on September 29, 1997. However, the test was cancelled when the vessels (which were both provided by Clean Coastal Waters, an oil spill response company) were recalled due to an oil spill in Santa Barbara.

For test #4, all five tracer gases were released from two different vessels (see Figure IV-4). Two tracers were released as stationary point sources within the current shipping lane. Two separate tracers were released as stationary point sources, at two different locations (one from the proposed shipping lane, the other was off-course due to human error by the vessel's Captain). The remaining tracer was released as a moving source within the current shipping lane. Table IV-6 summarizes tracer test #4.

Table IV-6
Summary of Tracer Test #4
(October 4-5, 1997)

Shipping Lane	Tracer	Release Type	Release Start Time	Release End Time	Tracer Released (g)	Average Release Rate (kg/hr)	Average Vessel Speed (mph)
Current	PDCH	Stationary	0600	0800	2,970	1.49	0
Off Course	PTCH	Stationary	0600	0800	2,950	1.48	0
Current	PDCB	Moving	0400	0600	3,285	1.64	17.6
Current	PMCH	Stationary	1100	1300	3,255	1.63	0
Proposed	PMCP	Stationary	1100	1300	3,190	1.60	0

Following each tracer test, the collected air samples were shipped to Brookhaven National Laboratory (BNL) for analysis to determine the concentration of each tracer gas from each sample. In the section below we describe the tracer measurements and analysis of the tracer data.

Figure IV-3
Tracers and Release Locations for Test #2

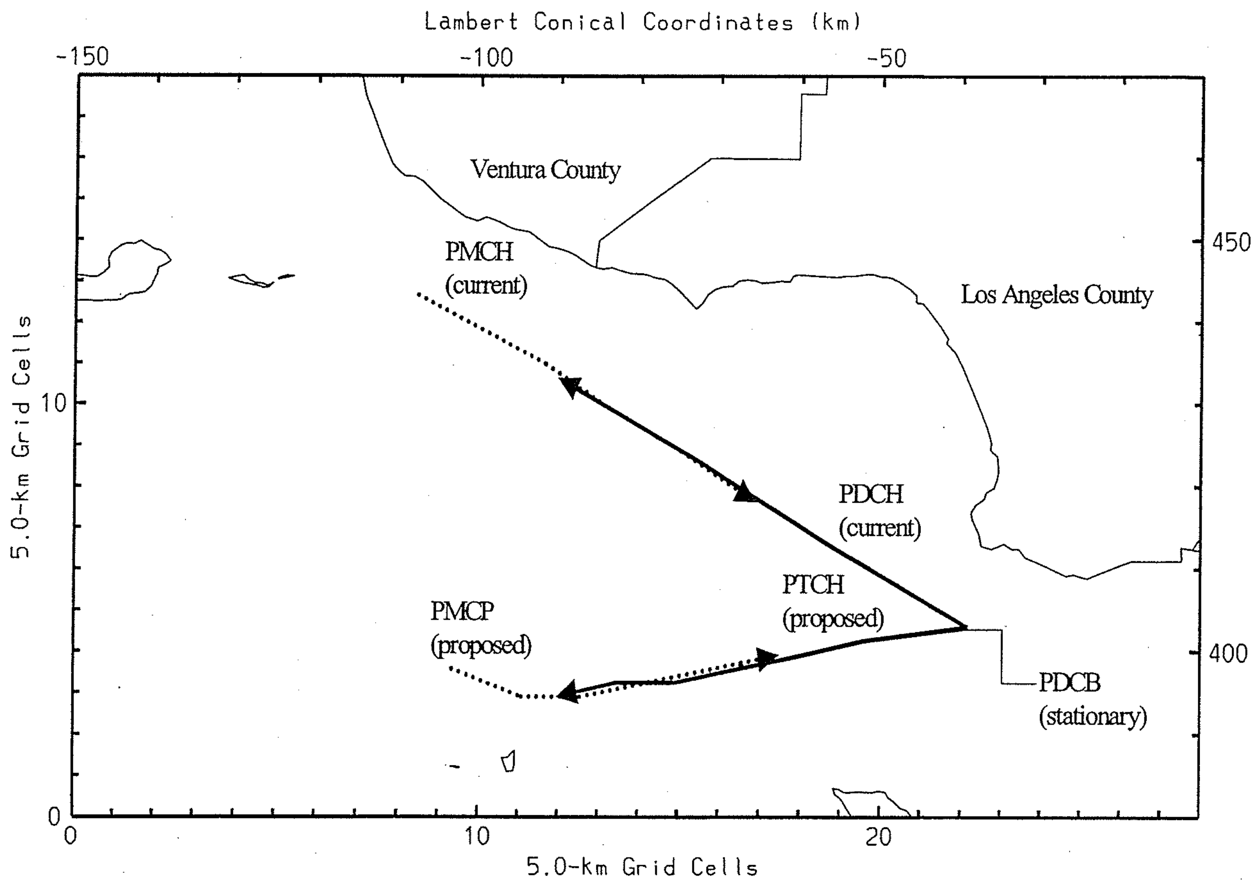
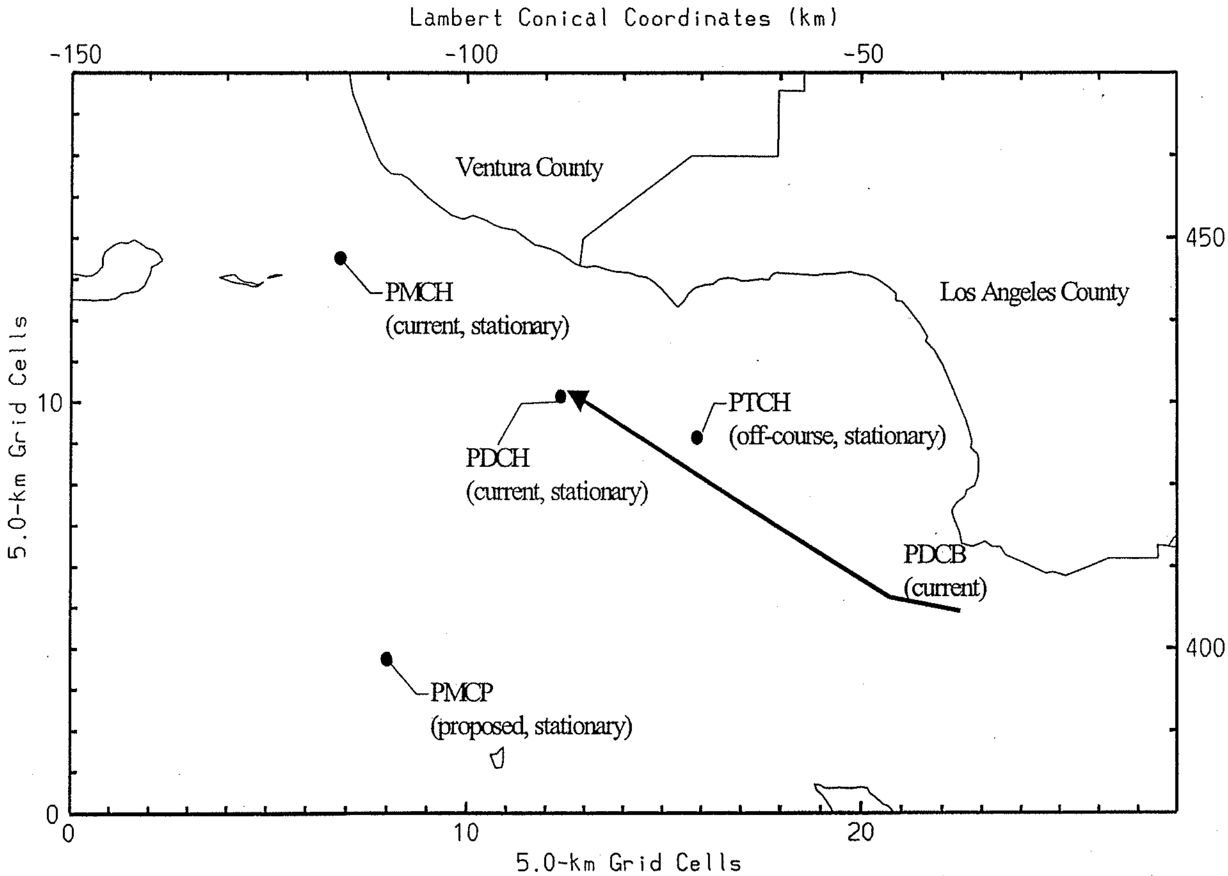


Figure IV-4
Tracers and Release Locations for Test #4



B. ANALYSIS OF TRACER DATA

Quality Assurance

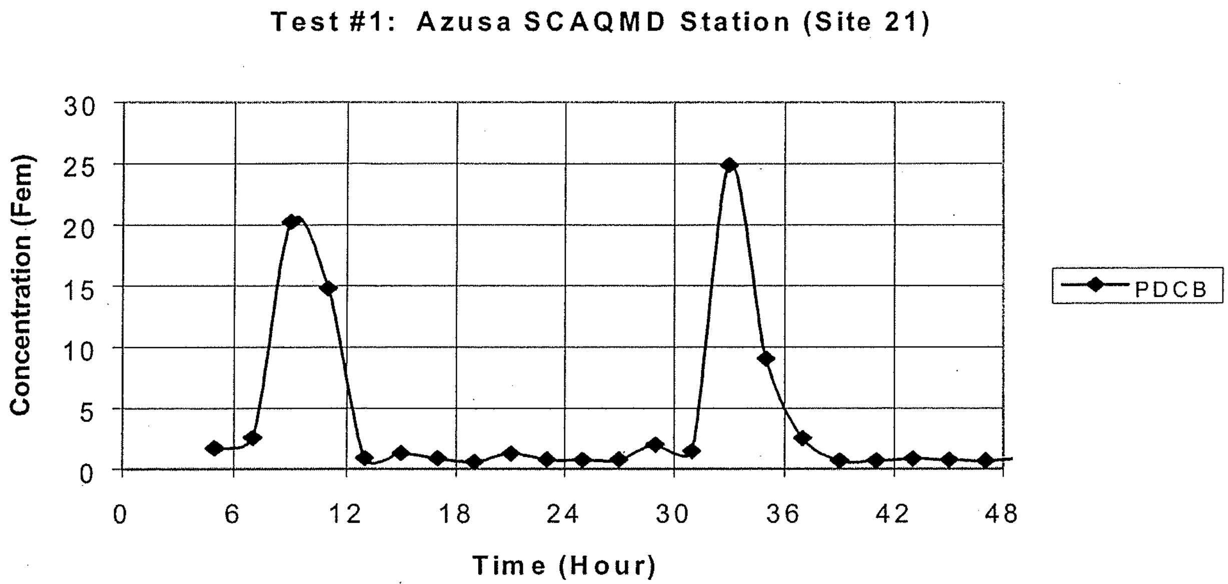
To ensure the overall quality of the tracer data, the ARB conducted an internal quality assurance (QA) review of the data sets containing the measured tracer concentrations. This analysis was an extension of the equipment and laboratory QA performed by the contractors.

BNL provided the tracer data in two Excel spreadsheets, one for the BATS data and the other for the CATS samplers. Each spreadsheet contained results for the three tracer tests. The BATS spreadsheet described the data set and contained the BATS data. The CATS spreadsheet contained the 24-hour average CATS data and the data from the two background tests. As part of their laboratory QA, BNL flagged as bad any data where: a) the tube was not used (last tube in lid or interim shutdown tube); b) the pump may have failed, the tube leaked badly, or the tube was plugged; or c) the sample was lost during analysis. The documentation provided by Brookhaven described analysis procedures, including procedures used to adjust the observed tracer concentrations to account for background concentrations and to identify bad or questionable data.

The data review conducted by the ARB consisted of two components: the first to review the data sets sent to the ARB by BNL to verify their completeness and clarity; the second was to review the data for outliers or otherwise questionable or non-representative data. It also included the preparation and analysis of time series and spatial plots of measured tracer concentrations. These analyses illustrated a number of artifacts in the tracer data sets not identified by Brookhaven. Significant tracer concentrations were measured prior to tracer release times and there were tracer concentrations that were much larger than at surrounding measurement sites. Many of these artifacts were identified by the ARB with flags in the data set to distinguish them as "questionable." Others were assumed to indicate significant background concentrations or interferences to the tracer measurement techniques. In addition, the methodology used by BNL to estimate concentrations above background resulted in some negative values; these values have been flagged to be treated as zero.

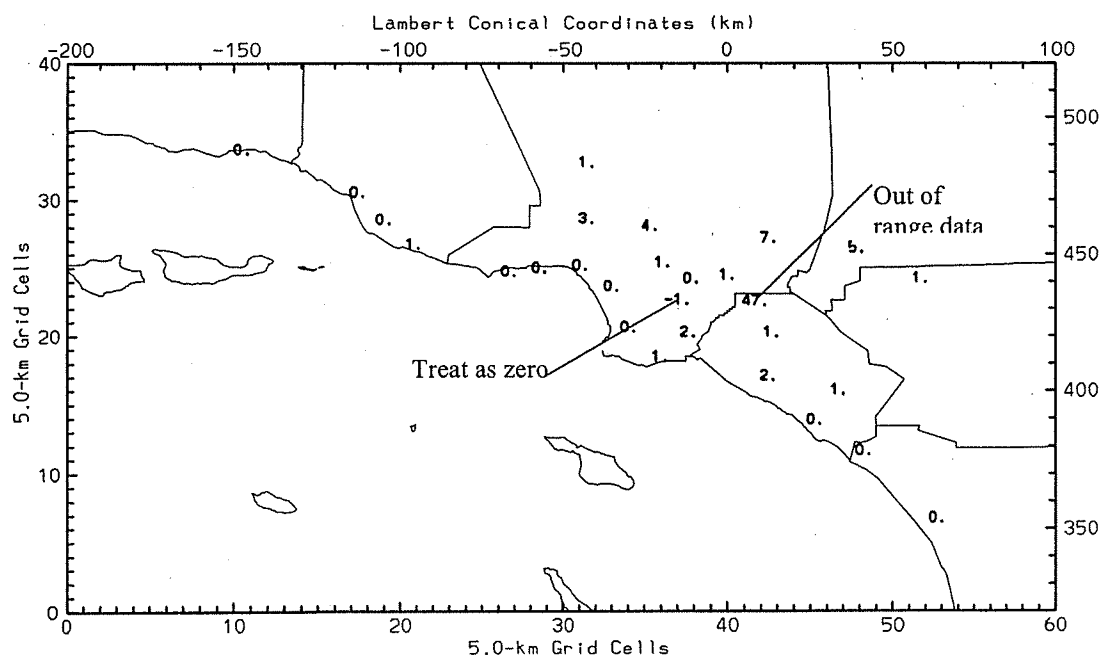
Three types of methods were used to check the tracer data: spatial plots, time series (temporal) plots, and inter-comparisons between the four co-located BATS and CATS samplers. The BATS data for each site were plotted temporally to check the diurnal consistency of the data. Figure IV-5 below shows an example of such a temporal plot.

Figure IV-5
Sample Temporal Plot



The data were also plotted spatially, to check for consistency with nearby sites. Figure IV-6 shows a sample spatial plot.

Figure IV-6
Sample Spatial Plot
(8/24/97 at 5 p.m. for PMCP)



Finally, the BATS and CATS data were inter-compared at the 4 co-located sites. The results of that comparison are shown in Tables IV-7 through IV-9.

Table IV-7
BATS vs. CATS Comparison for Tracer Test #1 (August 23, 1997)

Site	Date	PDCB		PMCP		PMCH		PDCH		PTCH	
		BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS
10	8/23	2.45	0.5	0.94	1.3	2.94	4	0.23	0.26	0.48	0
10	8/24	2.71	0.2	0.23	0.5	2.76	2.8	0.25	0	0.11	0
11	8/23	1.39	1.2	3.46	13.6	73.82	43.4	0.54	0.19	0.5	0.4
11	8/24	N/A	0.9	N/A	3.9	N/A	6.5	N/A	0	N/A	0.5
12	8/23	4.44	2.5	0.41	7.5	119.89	211.6	1.37	1.29	0.07	0
12	8/24	0.72	1.6	0.47	4.2	0.49	7.7	0.06	0.52	0.13	0.4
15	8/23	0.82	Bad	0.7	0	2.7	82.1	1.84	12.86	0.12	0.1
15	8/24	0.68	15.3	7.25	7.3	2.02	7	0.43	0	1.2	6.4

Table IV-8
BATS vs. CATS Comparison for Tracer Test #2 (September 4, 1997)

Site	Date	PDCB		PMCP		PMCH		PDCH		PTCH	
		BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS
10	8/23	N/A	0.3	N/A	0.9	N/A	3.4	N/A	0	N/A	0
10	8/24	0.86	0.5	0.54	3.3	2.5	4.1	0.19	0	0	45.8
11	8/23	2.11	0.4	16.39	11.7	2.67	3.2	0.23	0.83	0.77	9.4
11	8/24	1.06	1.6	10.65	10.6	2.68	10	0.2	0.79	0.19	0.6
12	8/23	0.46	1.8	0.37	25	154.6	126.4	0.05	1.05	0.05	3.3
12	8/24	11.35	8.1	9.44	8.3	4.11	23.4	0.5	0	0.72	0.7
15	8/23	0.62	1	0.47	0.7	34.56	40.1	0.51	0.44	0.11	0.8
15	8/24	0.83	N/A	10.55	N/A	1.98	N/A	0.07	N/A	0.19	N/A

Table IV-9
BATS vs. CATS Comparison for Tracer Test #4 (October 4, 1997)

Site	Date	PDCB		PMCP		PMCH		PDCH		PTCH	
		BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS	BATS	CATS
10	8/23	31.24	6	1.3	0	0.18	0.2	4.79	2.73	3.66	12
10	8/24	3.58	1.8	3.91	1.4	1.45	3.5	2.31	1.72	3.88	6.4
11	8/23	22.53	10	9.83	13.7	0.44	10.1	3.76	1.76	1.16	1.9
11	8/24	2.48	3	9.65	8.7	0.97	5.9	2.56	1.42	2.61	2.1
12	8/23	26.44	11.9	3.84	24.5	0.27	3.6	2.33	1.34	0.45	1.1
12	8/24	2.2	7.5	13.12	23.1	1.44	16.4	2.31	2.04	2.49	2.5
15	8/23	60.74	30.2	113.74	72.1	0.29	5.8	3.32	2.15	0.59	0.8
15	8/24	2.63	7	12.38	24.1	1.23	25.7	2.72	1.02	2.01	3.9

In most instances the two data samplers appear to track reasonably well, being relatively high or low at the same time. However, the concentrations do not agree consistently in magnitude or in which is higher. Because they are passive samplers, the CATS samplers are less reliable than their BATS counterparts, for which a known volume of air is pulled through the samplers. After discussions with Tracer ES&T regarding this issue, it was agreed that the CATS data should not be used for any of the subsequent technical analyses.

The final product of the QA process is a set of updated spreadsheets with appropriate flags included.

Normalization

As described previously, a series of three tracer tests were conducted to measure the atmospheric impacts from releases in the existing and proposed shipping lanes. The release configurations (amounts released and ship speeds) varied between the releases. Also, different tracer compounds were used in each test to represent the different shipping lane releases; these included a release from the point of separation, and morning and afternoon releases from each of the shipping lanes, as described previously. In order to account for these differences, the data were normalized. The results of the normalization allow a more direct comparison between similar time releases during an episode. Thus, for example, it is possible to directly compare differences in dispersion between the morning releases for the existing and proposed shipping lanes, and between the afternoon releases for each of the releases.

The data were normalized using a two-step procedure. First, the data for all three tracer tests were divided by the average mass of tracer released during the first two hours of each release, since the sampling resolution of the bulk of the BATS samplers was two hours. The few BATS samplers with one-hour resolution were converted to two-hour averages prior to this step. Table IV-10 summarizes the mass released during the first two hours for each of the tracers and episodes.

Table IV-10
Average Tracer Mass Released During First Two Hours (g/hr)

Tracer Test	Tracer				
	PDCB	PMCH	PMCP	PDCH	PTCH
August 23, 1997	1607.40	1310.04	880.20	1055.16	1169.64
September 4, 1997	470.00	730.00	1597.46	1620.00	1001.52
October 4, 1997	1642.68	1627.56	1595.16	1485.00	1474.92

After this step, daily station peaks were determined for all sites for the three tracer release days. The station peaks in Ventura County, San Diego County, and the SCAQMD were then separately averaged, to serve as an indicator of the extent of the tracer plume impacting each area. In order to avoid the inclusion of stations with no true peak, i.e., with background values, only stations with non-normalized tracer concentrations greater than 5 femtoliters/liter (fl/L) were included.

A second adjustment was then made to the station peak averages for the moving point source releases to account for differences in ship distance traveled during the first two hours of each release. In this step, ship- and test-specific adjustment factors were developed from each set of morning and afternoon releases for the August 23 and September 4 tracer tests. Factors were not developed for the October 4 tracer test because that test was comprised of predominantly stationary (non-moving) releases.

For the morning and afternoon of each test, ship-specific adjustment factors were calculated as follows:

$$K_1 = \frac{\overline{L}}{L_1} \quad ; \quad K_2 = \frac{\overline{L}}{L_2}$$

where K_1 = adjustment factor for the release vessel in the existing shipping lane

K_2 = adjustment factor for the release vessel in the proposed shipping lane

$\overline{L} = \frac{L_1 + L_2}{2}$ = average distance traveled by the release vessels in the existing and proposed lanes

L_1 = distance traveled during the first two hours of the release by the vessel in the existing shipping lane

L_2 = distance traveled during the first two hours of the release by the vessel in the proposed shipping lane

Table IV-11 shows the adjustment factors obtained using this methodology.

Table IV-11
Ship- and Test-Specific Adjustment Factors (K) for Distance Traveled

Tracer Test	Morning Releases		Afternoon Releases	
	Current Shipping Lanes (PMCH)	Proposed Shipping Lanes (PMCP)	Current Shipping Lanes (PDCH)	Proposed Shipping Lanes (PTCH)
August 23, 1997	0.8733	1.1697	1.0179	0.9828
September 4, 1997	0.9378	1.0711	0.9279	1.0843

It should be noted that the above normalization is a first order correction to boat speed which is valid only if the release vessel speeds are similar in magnitude.

As the final step in the normalization process, the average of the station peaks for each tracer compound was then divided by the adjustment factors above for the August 23 and September 4 tracer releases; no adjustments were made to the October 4 results as discussed above. The resulting data serve as the basis for direct comparisons between the two shipping lanes. Table IV-12 summarizes the results of the normalization process.

Table IV-12
Results of the Normalization Process: Average Normalized Station Peaks (fl/L)*,**

	Morning Releases				Afternoon Releases			
	Current Shipping Lanes (PDCH)		Proposed Shipping Lanes (PTCH)		Current Shipping Lanes (PMCH)		Proposed Shipping Lanes (PMCP)	
August 23, 1997	avg.	*# stations**	avg.	*# stations**	avg.	*# stations**	avg.	*# stations**
Ventura County	0	*(0)*	0	*(0)*	0	*(0)*	0	*(0)*
South Coast AQMD	0.26	*(10)*	0	*(0)*	3.47	*(11)*	6.20	*(10)*
San Diego County	0.27	*(1)*	0	*(0)*	0	*(0)*	2.07	*(1)*
September 4, 1997								
Ventura County	0	*(0)*	0	*(0)*	0	*(0)*	0.04	*(1)*
South Coast AQMD	9.99	*(5)*	3.99	*(7)*	5.21	*(13)*	1.07	*(11)*
San Diego County	0	*(0)*	1.60	*(1)*	0	*(0)*	0.07	*(1)*
October 4, 1997								
Ventura County	N/A	N/A	N/A	N/A	0	*(0)*	0	*(0)*
South Coast AQMD	N/A	N/A	N/A	N/A	1.36	*(2)*	1.35	*(17)*
San Diego County	N/A	N/A	N/A	N/A	0	*(0)*	0	*(0)*

* *Only station peaks corresponding to non-normalized concentrations > 5 fl/L were included during the averaging process to avoid including background values; the numbers in parentheses indicate the number of station peaks satisfying this criterion.*

** *The August 23 and September 4 tracer releases were adjusted to account for ship distance traveled; the October 4 release was not, because the release was stationary.*

As an aid to interpreting the results of the normalization process, ratios of the impacts (average normalized station peaks) from the proposed shipping lane to those in the current lane for the South Coast AQMD were developed for each of the comparable releases. These ratios are presented in Table IV-13.

Table IV-13
Ratios* of Proposed Shipping Lane Impact to Current Shipping Lane Impact in the South Coast AQMD

	Ratio for Morning release	Ratio for Afternoon Release
August 23, 1997	0	1.79
September 4, 1997	0.40	0.21
October 4, 1997	N/A	0.99

* *The ratio of average normalized station peak concentrations for the proposed lane to that from the current lane, from Table IV-12 above.*

As defined, ratios less than 1.0 in the above table imply greater dispersion from the proposed lane. Conversely, ratios greater than 1.0 imply less dispersion from the proposed lane. Ratios near 1.0 imply similar dispersion for the two lanes.

Tables IV-12 and IV-13 suggest the following qualitative conclusions from the tracer study:

- There is greater dispersion from the proposed shipping lane for some, but not all, of the tracer releases. For one release there was no discernable difference between the two lanes, and for another there was a disbenefit.
- The results strongly suggest that meteorology influences the direction and magnitude of dispersion benefits for the proposed shipping lane.

References

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